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THE OCCURRENCE OF *HELMINTHOSPORIUM SATIVUM* IN RELATION TO PRIMARY INFECTIONS IN COMMON ROOTROT OF WHEAT[1]

P. M. SIMMONDS,[2] B. J. SALLANS,[3] AND R. J. LEDINGHAM[4]

Dominion Laboratory of Plant Pathology, Saskatoon, Sask.

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INTRODUCTION

Common rootrot is a name given to a complex manifestation of disease in cereals, resulting from the invasion of the crown and roots by certain fungi. *Helminthosporium sativum* P.K. and B. is considered of first importance in this type of disease in wheat and barley. It is known to be widely distributed in the extensive grain growing areas of Western Canada. In this paper, the authors will endeavour to bring up to date observations on the distribution of the pathogen, particularly in Saskatchewan, and present some recent data on primary infections.

A rather extensive literature review was made in seeking recorded observations on primary sources of disease. Bolley (3) was obviously aware of the prevalence of lesions on the wheat plant at, or near, the soil line; and he illustrated (p. 20) a typical lesion on a young wheat plant. He considered that most of these lesions were caused by *H. sativum*, and suggested that the fungus comes from stubble pieces or infected seed. He stressed the importance of diseased seed.

Seed, as a source of infection, was reported by Louise J. Stakman (21), who also mentioned the probability of infections from the soil. Infected seed and infested soil were stated to be sources of primary infections by Christensen (4), who conducted greenhouse and field experiments with wheat and barley. He noted the abundant sporulation from lesions and considered wind the chief factor in dissemination. In her studies of *H. sativum*, Dosdall (6) made some inoculations in pot experiments by pouring a conidial suspension over the surface of the soil. A similar method of inoculation was employed by McKinney (13). The method is of interest to the authors, as will be seen later. Christensen (5) observed primary lesions on wheat and barley sown at intervals from April to October. In Saskatchewan, Sallans (14) found that lesions appear on the subcrown internode of wheat in greatest abundance, commencing early in July. It was well known to most investigators of common rootrot that seedlings growing in infested soil soon became infected; but the source, whether conidia, or mycelium in the soil, or pieces of stubble in which the fungus was established, was not easily determined.

[1] Contribution No. 1036 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

[2] Plant Pathologist in charge.

[3] Associate Plant Pathologist.

[4] Assistant Plant Pathologist.

Shortly after this period, there followed the pioneering research of Sanford and Broadfoot (17) and Henry (9), which showed the influence of soil microorganisms in suppressing root disease pathogens. Their work placed the interpretation of cereal root pathogenesis on a much sounder basis. Henry (10) later came to the conclusion that conidia of *H. sativum* were very rare in Alberta soils. He thought this fungus must exist there in the form of mycelium. In his earlier work (8) also, he was unable to isolate it from soil. Bisby, James, and Timonin (1, 2), in extensive isolations from Manitoba soils by the plate method, obtained only a few colonies of *H. sativum*. By this method, they were unable to determine whether the colonies originated from conidia or mycelial fragments, or from both. Generally speaking, the importance of conidia, in nature, was not stressed in regard to primary lesions, although Christensen (4) emphasized their importance in dissemination. Diseased seed, however, was considered a very important source, and may explain the common tendency for the development of various methods of seed inoculation.

OCCURRENCE AND DISTRIBUTION IN SASKATCHEWAN

Several years ago, isolation work was conducted in an effort to determine the distribution of root-disease fungi, chiefly *Helminthosporium sativum* and *Fusarium spp.* This work was reported in the Dominion Botanist's Reports for 1927 to 1930, inclusive (18). Wheat specimens were received from Morden, Winnipeg, Indian Head, Saskatoon, Swift Current, and Edmonton. The results showed that these fungi were prevalent in Manitoba, Saskatchewan, and Alberta. There appeared to be a seasonal fluctuation in the occurrence of *H. sativum*. Regional differences were inconsistent for the six source locations, with one exception: the Edmonton material invariably gave fewer *H. sativum* isolates. Isolation work by Simmonds and Ledingham (19) showed that infections of *H. sativum* were pretty well confined to the crown and adjacent tissues. These findings directed our attention to surface litter, such as cereal stubble, as a possible source of infection.

This approach was explored by Ledingham (12). He collected two soil samples from each of seven different rotations and, in addition, two samples from virgin sod. One series of samples included the top soil and surface litter, and the other series was of soil just below the surface, which was comparatively free of litter. Six-inch pots were filled with the respective soils and seeded with Thatcher wheat. The pots were kept watered and the seedlings grew at the usual fluctuating summer temperatures. They were kept in a laboratory window. The seedlings were harvested at the end of a three-week period, and notes were made regarding the degree of development of lesions at their bases. Disease rates were computed, and it was found that there were no differences that could be attributed to rotations. In every case, however, there was more disease with litter present in the soil than with soil alone. The virgin sod samples showed the lowest disease rate in the series. *H. sativum* was readily obtained from most of the lesions.

A greenhouse test was conducted to compare soil with and without litter, at a low and a high moisture level. A disease rate was determined from lesions which appeared on the seedlings growing in the soil. Here

again, the soil containing litter showed the highest disease rate, regardless of moisture level. However, where litter was present, high moisture tended to depress infection. In the soil without litter, there was little difference between high and low moisture content. The low disease rate, at high moisture plus litter, was considered to be related to the increased microbial activity promoted by the litter. When, however, the soil moisture level was low with litter present, the disease rate was high, being about double the rate for soils without litter. The importance of field surface litter, consisting of stubble in most grain fields, was definitely indicated in these preliminary experiments.

In 1943, the senior author undertook a survey to determine the prevalence of *H. sativum* on stubble in wheat and barley fields. Fragments of wheat and barley straw were collected from summer-fallowed fields. It was thought that by collecting only from fallowed fields more uniformity would be obtained. All fields presented a similar history: wheat or barley crop, followed by a second crop of wheat or barley, then cultivation in the spring or early summer, climaxed by complete fallow by mid-summer. The specimens were collected in the summer. There was one important difference between the fallowed fields: some were cultivated, with most of the stubble being buried, whereas others were left with a layer of stubble and weed trash over the surface. This latter practice is common in the south and southwest as a soil drifting control. Notes were not made at the time regarding this difference, but later work indicated its possible influence on the occurrence of *H. sativum*. Collections were made around a town or village, which served as a central point. The distance between fields averaged several miles. The stubble samples were kept dry, and, later, representative specimens were incubated in the laboratory. The specimens, 100 from each field sample, were pieces of about one-inch length, including the crown. They were thoroughly washed under a tap, then placed on moist filter paper in Petri dishes. They were incubated for four days at 24° C. at the end of which sporulating growths of *H. sativum* could be determined. Eight regions were surveyed in 1943 and eleven in 1944. The results for 1944 are shown in Table 1.

TABLE 1.—PERCENTAGES OF WHEAT AND BARLEY STUBBLE SHOWING A SPORULATING GROWTH OF *Helminthosporium sativum*

Location	Field number										Average
	1	2	3	4	5	6	7	8	9	10	
	%	%	%	%	%	%	%	%	%	%	%
Swift Current	4	7	3	1	1	3	5	2	3	5	3.4
Yorkton	13	12	2	5	6	5	16	10	7	17	9.3
Pontiex	19	2	5	9	2	10	5	3	9	20	8.4
Rosetown	9	4	8	8	9	1	13	2	0	2	4.7
Tisdale	10	2	8	9	4	2	6	12	8	5	6.6
Saskatoon	0	16	2	0	2	4	2	2	9	3	4.0
Weyburn	7	2	0	4	7	5	9	1	1	3	3.8
Indian Head	22	13	8	23	3	19	15	4	3	12	12.2
Kennedy	14	8	8	4	10	2	13	15	18	1	9.3
North Battleford	3	0	7	0	4	5	6	3	0	4	3.2
Birch Hills	0	10	11	2	0	8	22	12	14	3	8.2

The most interesting feature of the tabulation is the marked fluctuations between fields. The data are too limited to bring out definite regional differences, but, so far as they go, they do not indicate a trend in that direction. The differences between fields in respect to the occurrence of *H. sativum* are very conspicuous. Fluctuations in its occurrence between fields were noticed also in 1943. A similar fluctuation in common rootrot infections, as determined by surveys, has also been observed by Sallans (16). His data, however, showed some evidence of regional differences in disease occurrence.

Collections were made of miscellaneous field litter to determine the occurrence of *H. sativum*. The collections were made in the fall near Saskatoon and included fragments of grass straws, alfalfa stems, stems of various weeds, and wheat stubble. The specimens were washed and set up in a moist chamber to incubate; *H. sativum* was obtained only from the wheat stubble. It appears therefore that cereal stubble, especially of wheat and barley, is the main site of *H. sativum* colonization.

CONIDIA ON STUBBLE AND IN SURFACE SOIL

Stubble and soil samples were collected in 1949 just after harvest and examined for *H. sativum* conidia. Pieces of stubble were examined with a binocular and the presence of conidia was recorded. Samples of surface soil from the same fields were vigorously shaken in water. After the larger soil particles had settled, the supernatant fluid was filtered, and the filter paper examined for the presence of conidia. It was realized that many, if not most, of the conidia would settle down with the soil residue. A sufficient number, however, usually remain floating to give an indication of their presence. The results are given in Table 2.

In the previous year, some soil samples were examined for the presence of *H. sativum* conidia by means of the suspension-filtration method. Conidia were quite readily found in soil collected at widely separated points, including Saskatoon, Indian Head, Raymore, Borden, Denholm, Rosetown, Shellbrook and Fielding. Conidia were difficult to find in soil from a few other locations.

TABLE 2.—NUMBER OF PIECES OF WHEAT STUBBLE BEARING CONIDIA OF *H. sativum* TOGETHER WITH RECORDS OF CONIDIA FROM SOIL SAMPLES COLLECTED AT THE SAME LOCATIONS

Location	Stubble pieces		Soil samples
	Number examined	Number bearing conidia	Conidia
Dalmeny	26	15	Few
Langham	27	17	Few
Radisson	23	10	Few
Fielding	23	10	Few
Prince	30	11	Many
Zealandia	25	2	Many

VIABILITY

The viability of the conidia found in the soil and on the stubble is of course important from a pathological standpoint. The conidia caught on the filter papers, as in the above test, were placed in Petri dishes to observe germination. It was generally found that conidia on filter papers moistened with a soil suspension would not germinate. It was thought that antibiosis set up by the soil flora inhibited germination of the conidia. Some experiments on this point will be discussed below. Almost invariably, the conidia germinated readily when picked off the soil-contaminated paper and placed on clean, moist filter paper. In some germination tests with soil solutions, mycelial fragments of *H. sativum* put out new growth, although nearby conidia failed to germinate.

Viable conidia were found in various soil samples. A sample of field soil was collected on May 13, 1948, near Saskatoon, and conidia taken from it were found to be viable. In this particular case, it seemed unlikely that these conidia were produced in the spring, as the weather had continued cool. Samples were taken from the same field on April 15, 1949, and viable conidia were found. It was, therefore, assumed that conidia remained in or on the top soil throughout the winter, and were viable. That conidia will remain viable for long periods, at least in dry soil, was indicated by testing conidia from a sample of soil which had been collected at Shellbrook in the fall and kept in dry storage all winter. The conidia were viable when tested in May. Christensen (5) found conidial viability to be maintained for long periods, even under adverse conditions.

Further information on viability was obtained by mixing conidial suspension of *H. sativum* with soil. A heavy suspension taken from cultures on potato dextrose agar was mixed with soil and the mixture placed in two Petri dishes. One dish was allowed to dry out, whereas the other was kept damp. Conidia were taken periodically for testing from both dishes. Viable conidia were still obtainable after a period of seven months. The dry soil mixture was kept and tested after twenty-three months at which time a few conidia were found to be viable. A comparable experiment was conducted in which the conidia were sprayed on to pieces of stubble kept dry in a Petri dish. When moisture was added periodically to the dish to provide conditions for incubation, the conidia on the stubble failed to germinate. If, however, they were picked off and placed on clean, moist filter paper, germination took place. This evidence supports the conclusion that the natural flora on the stubble inhibited germination.

The widespread occurrence of viable conidia in grain fields would indicate that they play an important role in primary infections in the common rootrot disease of wheat and barley.

INOCULATIONS

Information on primary infections was obtained by means of conidial suspensions in greenhouse experiments. One such pathogenicity test is outlined and discussed. Quarter-gallon crocks filled with unsterilized soil were employed. Five crocks, sown with 40 seeds each, represented the inoculated, and five similarly prepared formed the uninoculated series.

Immediately after the seed had been sown and covered, the first series was inoculated by washing a small amount of a heavy suspension of *H. sativum* over the soil surface. A day or so after the seedlings had emerged, tiny lesions were noticed on the coleoptile, at the soil surface, in the inoculated group. The lesions developed rapidly and were very distinct on the eleventh day, when the plants were harvested. The results are given in Table 3.

The results show a successful inoculation. Many experiments have been conducted in the greenhouse in which the ease of inoculation by washing a conidial suspension over the soil, before or after seedling emergence, has been demonstrated conclusively. There are, of course, many factors which may interfere with successful infections, such as soil temperature, moisture conditions, and soil type.

Only one inoculation experiment was made in the field and, although heavy infections occurred, the results were inconclusive: the check blocks became infested during a long, dry period in which surface soil blew about carrying inoculum with it.

INFECTIONS IN THE FIELD

Field surveys for root diseases were made during the summer. Particular attention was given to the appearance of lesions on wheat seedlings near the soil surface. *H. sativum* produces a rather characteristic lesion that is not likely to be confused with other infections. On one trip in June, records of lesions were kept and are shown in Table 4.

TABLE 3.—NUMBER OF WHEAT SEEDLINGS WITH OR WITHOUT LESIONS

Treatment	Number of seeds sown	Number of seedlings	
		With lesions	Without lesions
Inoculated	200	194	5
Not inoculated	200	14	176

TABLE 4.—PERCENTAGES OF WHEAT SEEDLINGS BEARING LESIONS NEAR THE SOIL SURFACE, RECORDED ON A SURVEY TRIP IN JUNE, 1949

Location	Seedlings with lesions	Location	Seedlings with lesions
	%		%
Guernsey	Trace	Viceroy	50
Fort Qu'Appelle	Trace	Limerick	40
Dafoe	100	Kincaid	80
Indian Head	100	Ponteix	65
Cupar	80	Ponteix west	40
Qu'Appelle	90	Cadillac	45
Francis	30	Masefield	60
Cedoux	50	Cadillac north	60
Trossachs	10	Elrose	10
Ogema	40	Rosetown	30

The data in Table 4 show that lesions near the soil surface are rather common. On the whole, there were more heavily infected wheat crops in the drier than in the moister areas, but there were high records also for some fields where moisture was ample. Specimens were collected from five of the fields, and pieces bearing lesions were incubated to determine the presence of *H. sativum*. The results are shown in Table 5.

TABLE 5.—NUMBER OF WHEAT SEEDLINGS BEARING LESIONS WHICH PRODUCED *Helminthosporium sativum*

Date	Locality	Number of specimens incubated	Number showing *H. sativum*
June 22	Blucher	8	3
June 22	Viscount	10	8
June 22	Dafoe	37	26
June 22	Cupar	40	27
June 24	Cadillac	24	19

The results from the incubation tests indicate that many of the lesions observed in the survey were caused by *H. sativum*.

SOIL-BORNE CONIDIA AND ANTIBIOSIS

There appears to be good evidence to show that certain microörganisms may inhibit the germination of conidia of *Helminthosporium sativum*. Such inhibition is indicated for soil solutions in the above-mentioned results on viability. The same phenomenon was observed in a study of the microflora of cereal seeds and stubble in relation to this fungus (20). Evidence of a like nature was found by Henry (9, 10) and others. It seems apparent, therefore, that conidia of *H. sativum*, in order to cause infection, must surmount the antibiosis they encounter from soil microörganisms. They must also overcome the same antibiosis before they can initiate a saprophytic development of the fungus in the soil or on crop debris.

In the opinion of the authors, the development of *H. sativum* in the field is restricted by the indigenous microflora. There is some evidence for this conclusion. When incubated stubble is examined for fungus growths, only small percentages of them, as a rule, are found to be *H. sativum*. It is thought that the sporulating colonies arise from previous infections of the culms. In earlier work, it was found difficult to inoculate unsterilized stubble pieces with conidia of *H. sativum*. An experiment conducted in the present study gives further information on this point. For the test, 500 pieces were selected from specimens collected near Saskatoon. They were washed under a tap, and 250 pieces were placed in Petri dishes fitted up as moist chambers, and allowed to incubate at 24° C. The remaining 250 were similarly set up, and inoculated with a conidial suspension of *H. sativum*. The results are shown in Table 6.

The results show that *H. sativum* was already established in about 14 per cent of the pieces of stubble. The inoculation did not greatly increase this percentage, thus indicating the difficulty of inoculating unsterilized stubble.

TABLE 6.—NUMBER OF PIECES OF WHEAT STUBBLE SHOWING *Helminthosporium sativum* AFTER INCUBATION, WITH AND WITHOUT INOCULATION, AT 24° C.

Treatment	Number of pieces	Number bearing *H. sativum*	Per cent
Incubated	250	35	14
Incubated after inoculation	250	39	15.6

The antibiotic flora found on stubble, considered here to be largely bacterial, probably arises from the soil. Presumably these bacteria are disseminated widely by wind and water. Many exploratory tests were conducted with soils and soil solutions to determine their influence on the germination of *H. sativum* conidia. As a general rule, germination was suppressed. However, when the soil solution was boiled for 10 minutes, the inhibitory effect was removed, thereby indicating the biological (bacterial) nature of the inhibition. Furthermore, non-germinating conidia in a soil smear or on incubated straws would germinate readily, as a rule, when picked off and placed on clean, moist filter paper.

Some preliminary tests were conducted with ultra-violet light and sunshine in an effort to destroy the antibiotic flora on the soil surface. In inoculation tests with *H. sativum*, treatments of the soil surface with ultra-violet light or sunshine tended to increase infection. Presumably the light treatments killed the antibiotic bacteria on the surface of the soil. The conidia on the surface, therefore, were able to germinate and cause infection without noticeable antibiotic interference. It seems reasonable to assume that, in nature, sunshine may play a similar role.

DISCUSSION

Surveys conducted over a period of years in Western Canada show the widespread occurrence of *H. sativum*, a root-disease pathogen of wheat and barley. A review of the literature indicates a similar prevalence in the extensive grain growing areas of the United States. Recent surveys in Saskatchewan show wide fluctuations in the prevalence of the pathogen or the disease from field to field. This feature of the disease has never been satisfactorily explained, although common rootrot has been studied by many researchers. Moreover, the onset of the disease, especially in regard to primary lesions, has not been explored thoroughly.

In the present studies, conidia of *H. sativum* were found to be abundant both on the stubble and in the surface soil of some fields. Many of the conidia were viable, even when taken from soil samples early in the spring. It is apparent, therefore, that they can survive the winter. Laboratory experiments demonstrated, furthermore, that conidia would remain viable for long periods in soil. It is believed that conidia, in or on the surface soil or on stubble, are a source of primary infections in the crop. Surveys in June revealed the common occurrence of infections in the crops, presumably from this source. Greenhouse experiments show that wheat or barley

seedlings were readily inoculated by washing a conidial suspension over the soil surface. Inoculations of this type could be made successfully either before or after seedling emergence.

It should be mentioned that the infection of seedlings near the soil surface permits the pathogen to enter the crown node or adjacent tissues. Hynes (11), Sallans and Ledingham (15), and Greaney (7) found that invasions at this point, with the subsequent destruction of crown and sub-crown internode tissues, tiller buds, and root initials, may cause serious injury under conditions favourable for disease development.

The conclusion that an abundance of *H. sativum* conidia may be found in or on the surface of the soil, makes it possible to formulate a seasonal cycle respecting disease incidence. Briefly, such a cycle may be outlined as follows: (1) conidia present in or on the surface soil cause primary infections; in time, new conidia are produced; and new infections occur throughout the crop season; (2) after harvest, conidial production continues on the stubble of plants which bore lesions. Thus, throughout the summer and fall, conidia are deposited on the soil, to be washed about by fall, winter, and spring rains. These conidia serve as inoculum for the next crop.

Conidia may also be moved about by high winds. It is thought, however, that they are not well adapted for air dissemination. They have rarely been present on spore-trap slides used in rust epidemiology studies in Western Canada.

It has been shown in the present work, in previous studies by Simmonds (20), and in investigations by others that *H. sativum* may be suppressed by other microörganisms. It would be expected, therefore, that conidia of this fungus on the soil surface would be exposed to rather active antibiosis by the indigenous flora. This antibiosis would fluctuate with changes in moisture, temperature, and sunshine. There would also be considerable variation in the number and kinds of microörganisms (bacteria) involved. Some support for the assumption of an antibiosis inhibitory to *H. sativum* was obtained by exposing the soil surface to ultra-violet light or sunshine. Such exposures, in inoculation tests, gave higher infections of seedlings than in comparable but shaded soils. The results of these tests support the hypothesis that the light treatments killed or inactivated the antibiotic bacteria on the soil surface, thus allowing the free development of *H. sativum*. It is believed that such phenomena could take place in nature.

The antibiosis in the top soil, which may inactivate conidia, is no doubt influenced by other environmental conditions brought about by cultivation, rotation, fertilizers, and so forth. Fluctuations, such as do occur, in the incidence of the disease from field to field and district to district might, therefore, be expected.

If conidia on the surface of the soil are as important as we believe they are in causing primary infections, then the surface soil becomes a pivotal point in devising methods of control. In this regard, attention should be directed towards ways and means, perhaps by cultural methods and rotations, whereby the antibiosis at the soil surface could be enhanced. Perhaps, also, antibiotic substances could be applied directly to the soil surface. On the other hand, it might be feasible in some instances to apply fungicides to kill surface-borne conidia.

SUMMARY

Survey records on the occurrence of *Helminthosporium sativum* in Western Canada are discussed. Wide fluctuations in incidence between fields was found.

It is shown that *H. sativum* exists in great abundance in some fields as conidia on the stubble or in the surface soil. These conidia retain their viability for long periods and frequently over winter. Experiments conducted in the greenhouse as well as field surveys indicate that such conidia are important in causing primary infection on wheat seedlings.

A seasonal cycle pertaining to the occurrence of the pathogen and the appearance of the disease is outlined.

Tests were conducted which showed that the germination of conidia of *H. sativum* was suppressed by the microflora on stubble or in the top soil. This microflora was considered to be largely bacterial. The influence of ultra-violet light and sunshine in retarding or killing the bacteria on the surface of the soil, without injuring the conidia, was indicated by experiments.

The possibility of employing the knowledge regarding conidia on or in the surface soil and information on the antibiosis of the soil flora in designing control methods is discussed.

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SPRINKLER IRRIGATION EXPERIENCE IN BRITISH COLUMBIA ORCHARDS[1]

J. C. WILCOX[2]

Dominion Experimental Station, Summerland, B.C.

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HISTORY OF SPRINKLER IRRIGATION IN BRITISH COLUMBIA

Sprinkler irrigation of orchards was started commercially in British Columbia about 1930. During the next five years, sprinkler installations were made in most of the orchards in the Creston district, and in a few orchards in the Penticton district. These early installations consisted for the most part of underground iron pipe, above-ground taps, garden hoses, and low-pressure undertree sprinklers of the butterfly type. This type of installation in some cases has been replaced recently by the portable pipe type; but as far as the author is aware, all of these orchards are still being irrigated by the sprinkler method.

In 1945 the portable pipe and quick coupler type of installation was first used in British Columbia orchards. Each year since then, many growers in the southern interior of the province have changed over from the furrow or rill method of irrigation to the sprinkler method, until at the present time approximately 30 per cent of the orchards in the irrigated districts are irrigated with sprinklers. The total area of orchards now under sprinklers is over 11,000 acres. Only one case has been reported to the author where a grower has changed from furrow irrigation to sprinkler irrigation and has then changed back to the furrow method. Almost all of the orchards are irrigated with low-pressure, undertree sprinklers. High-pressure, overtree sprinklers have been installed in only three orchards.

The usual type of sprinkler installation in British Columbia orchards consists of a screening box or tank to remove coarse dirt from the water; a pump and motor (where these are needed); an underground mainline steel pipe through the centre of the orchard; hydrants at intervals of 90 to 150 feet along the mainline; and portable sprinkler lines at right angles to the mainline, each 300 to 600 feet in length. A portable line usually consists of 2-inch aluminum tubing, in lengths of 20 to 30 feet, these lengths being held together with quick couplers. Rising from each coupler is a short ½-inch pipe topped by a rotary sprinkler. Each portable line is usually run for 12 hours along a tree panel, and is then moved to the next panel for the next 12 hours. Each panel is thus covered at intervals of 7 days to 30 days, depending chiefly on the type of soil.

After an initial study of sprinkler irrigation at this Station, recommendations were made to growers of tree fruits in 1946 to consider the sprinkler method favourably under the following circumstances:

1. Where soil erosion is in evidence.
2. Where the soil is sandy.
3. Where the contour is irregular.
4. Where the soil is saline.

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[1] Contribution No. 739 from the Division of Horticulture, Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Canada. Part of this paper was presented at the annual meeting of the Pacific Northwest Section of the American Society of Agricultural Engineers, held at Harrison Hot Springs, British Columbia, October 6-8, 1949.

[2] Senior Horticulturist in charge of Soils and Plant Nutrition Laboratory.

FIGURE 1. A portable line in operation in an orchard. It usually consists of lengths of aluminum tubing held together by quick couplers, with a sprinkler at each coupler.

No doubt the growers have been strongly influenced by these recommendations. They have, however, been influenced also by various other considerations. For example, some growers prefer sprinklers because they save water; others because they save labour. Some growers stress the ease with which they can grow a good cover crop under sprinklers, others the fact that couch (quack) grass does not worry them so much. Many reasons are given for the change-over by individual growers. It is worthy of note, however, that interest in the sprinkler method has been keenest where the contour of the land is steep or irregular and where the soil is sandy.

It is the major purpose of this paper to outline in brief the experience of tree fruit growers and the experience of the Experimental Station at Summerland with sprinkler irrigation during the past five years. To this end, conferences have been held with growers, irrigation district officials and sprinkler equipment agencies throughout the southern interior of the province; and in addition, most of the types of equipment used by growers have been placed under actual use tests at this Station.

In the past, the standard method of orchard irrigation in British Columbia has been the furrow or rill method. Due to steep and irregular contours, light soils, high cost of water and other factors, flood irrigation has not proved feasible for orchard irrigation. In assessing the value of sprinkler irrigation, therefore, it is only possible in this area to make direct comparison with furrow irrigation.

Favourable Experiences with Sprinkler Irrigation

The first beneficial effect observed from the use of sprinklers, as compared with furrow irrigation, has been a reduction in soil erosion. A high percentage of the orchards now under sprinklers are situated on slopes. Prior to the use of sprinklers, erosion had been serious in many of these orchards, especially where the soil was sandy. Each year considerable washing of soil occurred along the sides and bottoms of the furrows, and in some of the orchards examined the original surface soil had been completely lost after only 30 to 40 years of irrigation. An examination of these same orchards, made following the installation of sprinkler irrigation, has revealed only slight if any surface erosion from sprinkler irrigation. Where the grower has a sod grass or sod legume cover crop and does not cultivate during the growing season, erosion caused by sprinkling is usually too small to measure.

Under furrow irrigation, it is often difficult to obtain a good catch of the cover crop, especially between the furrows; and it is still more difficult to maintain it once it has caught. This is especially true between the furrows in sandy soils. Under sprinkler irrigation, most growers have been able to obtain an excellent catch of the cover crop, and to maintain it in a vigorous condition without difficulty. The standard practice is to plant a sod cover crop such as Kentucky blue grass or ladino clover, and to mow it, rather than cultivate it. Mowing helps to maintain the cover crop, and is cheaper than cultivation; in addition, it does not induce soil erosion as does cultivation. Mowing is much easier to perform under sprinkler irrigation than under furrow irrigation.

Most growers have expressed themselves as being glad to be rid of the furrows. They find them expensive to make and to maintain, especially in a sod grass cover crop such as couch grass. Moreover, with furrows present the ground is more uneven and orchard operations are more difficult to perform. Some growers report distinctly less bruising of the fruit during hauling, when furrows are absent.

An examination of the soil in a large number of orchards indicates that irrigation water is being applied to the soil much less uniformly by the furrow method than by the sprinkler method. This is especially true in sandy soils, where the soil is seldom wetted properly between the furrows. Even in clay soils, however, dry spots are frequently found between the furrows; for example, along the tree rows where the furrows are usually wider apart

Most growers have reported a distinct saving in water on changing from furrows to sprinklers. This saving usually amounts to about 10 per cent with heavy soils and about 35 per cent with sandy soils, although figures from zero to over 50 per cent have been reported. In some cases, the saving on sandy soil has been little, if any; and in such cases investigation usually reveals that under furrow irrigation there had not been sufficient water to maintain adequate soil moisture. In some such cases, however, the sprinkler system has been poorly engineered and the grower is using far more water than he should. Irrigation districts have reported savings averaging around 20 to 30 per cent, depending chiefly on the kind of soil in the district. Careful comparison made in sandy loam soils at the Experimental Station at Summerland and at the Substation at Kelowna, resulted in savings of about 30 per cent at each place over a period of three years. Some of this saving resulted from a reduction in amount of water lost into the deep subsoil below the furrows, some from elimination of the tailings water that runs off the lower ends of the furrows.

Preliminary investigations on water requirements under sprinkler irrigation have led to tentative recommendations for the southern part of the Okanagan Valley. These are summarized in Table 1. They apply to mature orchards with permanent sod legume or sod grass cover crops. The recommendations vary in accordance with the length of interval that can safely be allowed between irrigations, i.e., from as little as five days in a shallow sand or gravelly soil to as much as one month in a deep silt or clay loam.

Reports from all districts where sprinklers are in common use reveal that difficulties caused by tailings water and seepage water have been greatly reduced. In some orchards it has been found very difficult to control tailings water, and in many cases it has collected and run down the municipal roadway, over a bank, or through the neighbour's orchard, causing serious damage in its path. Seepage water has emerged lower down the slope or on the valley bottom and has induced both excess water and excessive salinity at that point. In some cases serious slides have been produced on the hillsides, due to weakening of the banks by seepage water. Complaints of such difficulties are seldom heard where sprinkling has become the general method of irrigation. Periodical examinations of drainage systems under a number of orchards have revealed a marked reduction in the flow of drainage water following the installation of sprinkler systems.

TABLE 1.—SPRINKLER IRRIGATION RECOMMENDATIONS FOR MATURE ORCHARDS IN SOUTHERN OKANAGAN VALLEY

Safe interval	Amount per application	Amount per month	Rate of flow per acre	Suitable length of irrigation	Rate of application per hour
days	inches	inches	g.p.m.*	hours	inches
5	2	12	6.3	8	0.25
7	2½	10	5.2	8	0.31
10	3	9	4.7	12	0.25
15	4	8	4.2	12	0.33
21†	5	7	3.7	12	0.42
	5	7	3.7	24	0.21
30	6	6	3.1	24	0.25

* Imperial gallons per minute.
† Two alternative rates of application are suggested, depending on the soil permeability.

In every case reported to the author, growers have claimed a saving in labour on changing to sprinklers. The saving claimed in the daily work of irrigation has varied widely, but usually falls within the range of 40 to 60 per cent. These high figures are possibly due in large measure to the fact that many of the orchards that were changed over to sprinklers were poorly adapted to furrow irrigation in the first place, so that labour costs had been quite high. The operator with sprinklers usually changes his portable lines twice a day, and spends the rest of the day conducting other orchard operations; whereas the man using furrows may have to spend most of the day adjusting the flow of water and cleaning out plugged furrows. In addition to this routine saving in time is the saving resulting from not having to make furrows once or twice each year and connect them up to the flumes by hand.

No experiments have been conducted in British Columbia to compare the effects of furrow irrigation and sprinkler irrigation on tree yield. The only yield-comparison records available are those provided by growers who have changed from furrows to sprinklers. These records, however, cannot always be relied upon, since yield comparisons are usually made in different years. Some growers report marked increases in yield following installation of sprinklers, especially with peaches and apricots in sandy soil. Observational evidence indicates that these yield increases are often due in large part to the use of sprinklers; but there is no experimental proof that such is the case.

Unfavourable Experiences with Sprinkler Irrigation

When sprinkler irrigation assumed importance in British Columbia orchards, it was feared that spray from the sprinklers would wet the leaves and fruit, and because of this would aggravate diseases or insect pests or possibly wash off the spray materials. On this account, it was recommended that undertree sprinklers with a low trajectory be used. Actually, the deleterious effects induced by wetting of the leaves and fruit have not proved to be as serious or as widespread as was feared. Numerous cases have been reported, however, where some damage appears to have been caused by sprinklers which have thrown their spray too high into the

trees. Brown rot of peaches appears to have been somewhat worse in such cases; also fire blight of pears. *Phytophthora cactorum*, which causes crown rot of apples, has caused rotting of apricot, peach and pear fruits. Reports on apple scab are somewhat conflicting; so also are the reports on splitting of cherries and apricots. There appears to be no doubt that under certain circumstances cherries are split more when wetted by sprinklers. Even though such cases of damage have not been widespread, overtree sprinklers are still not being recommended for general use.

Over-irrigation has been indulged in by a few growers with sprinkler systems. This has not only wasted water, but had in some cases caused actual damage. A case in point was where the grower has a heavy soil with poor drainage. Under furrow irrigation he had wasted a large percentage of the water over the ends of the furrows. When he changed to sprinklers, he continued to use his full quota of water and thus applied too much and nearly killed his trees. Such over-use of water is sometimes caused by poor engineering of the sprinkler system, sometimes by lack of understanding on the part of the grower.

Most growers have installed adequate screening boxes or drums at their intakes, to keep coarse dirt out of their sprinkler lines. Where this has not been done the sprinklers have plugged up and distribution of water has not been uniform. In some districts, however, difficulties have been encountered from fine dirt in the water, that stays in suspension and quickly wears out the sprinkler heads. The sprinklers may not turn at uniform rates in such a case, and replacement parts are needed frequently.

As already noted, it has become customary to grow sod grass or sod legume cover crops in sprinkled orchards. This has no doubt constituted one of the factors encouraging the present plague of mice. Although the mice are prevalent in clean-cultivated orchards, they are still worse in sod orchards. Present recommendations in British Columbia are for extermination with poison bait, as they have become a menace under any cultural conditions.

Some growers have complained that sprinkling brings the roots of the trees closer to the surface; and investigation has revealed that in many cases this is true. However, this of itself does not appear to constitute an undesirable effect. If the roots were to stop growing deep into the soil, then the situation would be more serious; but under normal soil conditions such an effect has not been found. No evidence has yet been obtained to indicate that the trees have suffered to any extent from having shallow roots as well as deep roots. Rooting in the fertile upper layers of soil may actually be an advantage.

Special Problems Due to Sprinkler Irrigation

When any new procedure is adopted by farmers, special problems arise that require special investigation. This has held true in the case of sprinkler irrigation in British Columbia. Some of the problems have been solved and some have not. A few of them will be mentioned in case they should prove of interest elsewhere.

Early in the investigational work on sprinklers, it was found that best distribution of the water was obtained when the sprinklers were placed in the centres of the tree squares. In order to accomplish this, the grower

FIGURE 2. Under furrow irrigation, soil erosion has proved to be much more severe than under sprinkler irrigation.

FIGURE 3. Under furrow irrigation, tailings water frequently collects and causes damage to roadways or to the neighbour's orchard.

FIGURE 4. A low-pressure type of sprinkler is usually used in orchards. It operates at optimum pressures of 20 to 30 pounds per square inch.

FIGURE 5. Poor engineering of a sprinkler system sometimes results in too rapid a rate of application of the water. This is more commonly found on heavy soils.

needed portable pipe in the same lengths as the tree spacing. At first the only length stocked by dealers was 20 feet. They are now stocking also 25- and 30-foot lengths, and other lengths can be obtained on special order. These "special orders" usually cost more. A common difficulty encountered is where a grower has two or more distances of planting in the same orchard, so that it would not be feasible for him to place every sprinkler in the middle of a tree square. On the whole, this problem does not appear to be a serious one at present.

Somewhat more serious is the problem of obtaining good equipment, that will give adequate service for a reasonable length of time. Second-hand pipe has been sold for underground use that has leaked badly when first used. The new 3- and 4-inch steel pipe in common use for the main lines is seldom heavier than 16-gauge. Sprinklers and couplers have been sold that were not suitable for orchard use. Such weaknesses have been due in part to lack of knowledge and in part to keen competition. Dealers find that in too many cases they must give low quotations on rather poor material if they are to obtain an order. In some cases, of course, suitable materials have not been available.

A similar difficulty has been encountered in the engineering of the sprinkler installations. Most growers know little about it until they have had some experience with sprinkling, and they cannot engineer their own installations. The equipment dealers on the whole have been doing a good job for them. Numerous cases have been encountered, however, where serious mistakes have been made. For example, systems have been designed that apply water much too rapidly to heavy soils; or that apply much more water than needed; or that use too high or too low a pressure, or that get around at too long an interval on sandy soils, or that place the sprinklers too far apart for adequate distribution of the water. Some of the mistakes made can be classified as engineering errors, some perhaps as due to lack of knowledge of irrigation requirements; and in some cases they may have been due to the dealer's desire to make low quotations on the equipment. The technical workers and the dealers are now co-operating in an effort to improve the situation with regard to equipment and engineering, and rapid strides have already been made toward this end.

As already noted, many of the orchards are planted on hillsides. It has been found difficult in many such orchards to operate all of the sprinklers within a reasonable pressure range. It has been recommended by this Station that the greatest and least delivery pressures at the sprinklers should not differ by more than 20 per cent of the highest pressure in any one orchard. To accomplish this, the portable lines are run on the contour wherever feasible, and the pressure in each line is regulated by the valve opening on to it. In some cases, however, a portable line will run uphill or downhill, thus causing wide variations in pressure. Various methods are in use for overcoming this difficulty, such as partial stops or valves along the portable line, or different sized sprinkler nozzles; or better still, a small valve under each sprinkler. Such methods are better than nothing, but are not entirely satisfactory.

Most of the fruit growers in the irrigated areas are grouped together into co-operative organizations called "Irrigation Districts". The districts impound the water and deliver it to each orchard, sometimes in flumes or

ditches, sometimes in pipes. It has been customary under furrow irrigation to measure the water to each orchard over an open weir. This is still done when the water is delivered in a flume to a sprinkled orchard. When it is delivered in a pipe, however, the grower does not wish to lose the pressure, and he objects to having this water measured over an open weir.

Among the methods being tried or considered for measuring the water without losing pressure are the following: (1) A meter large enough to handle the full flow. This is very expensive. (2) Tapping a small known proportion of the flow and passing this through a meter. (3) Using one meter to measure the proper flow at each orchard in turn, and locking the district valve at that point. A second valve is then required by the grower. (4) Inspecting each orchard periodically during the irrigation season to ensure that each grower is using the number of sprinklers, nozzle size and pressure that are required for the rate of water delivery allowed. So far, this last method has proved the most popular, in spite of its weaknesses. Little serious difficulty has yet been encountered in over-use of water by growers with sprinklers, as most of them have been using less water than districts allow for furrow irrigation.

Comparative Costs of Sprinkler and Furrow Irrigation

A question asked more frequently than any other in connection with sprinkler irrigation is: "How do the costs of this method of irrigation compare with those of other methods?" It has not been found possible to compare costs of sprinkler irrigation with those of flood irrigation in British Columbia orchards, but reasonably good comparisons have been obtained between sprinkler irrigation costs and furrow irrigation costs.

Costs of irrigation, as far as the orchardist is concerned, can be divided generally into the following categories:—(1) Cost of water; (2) Cost of equipment; (3) Annual operating costs (other than interest and depreciation), and (4) Effects on costs of other orchard operations.

1. Cost of Water. In some Irrigation Districts, water is paid for by the grower in two ways—first, as a tax on the per-acre basis, to pay for the costs of dams and delivery systems; and second, as a toll based on the amount of water used, to pay for current District operating expenses. Where the grower requires less water because he has changed to sprinklers, his toll charges are somewhat reduced. This has usually had only a minor effect on total costs.

In some Irrigation Districts, water is paid for on the per-acre basis only. In such cases the individual grower receives no direct reduction in water charges when he changes to sprinklers. When enough growers have changed to sprinklers, however, the District may find it has excess water on its hands, more land could be allowed to come under irrigation, and the per-acre charges could then be reduced somewhat; or more likely, these charges would not be increased as much as would otherwise be the case with a general increase in costs of materials and labour. It is very difficult to assess accurately such savings in costs.

2. Cost of Equipment. The cost of equipment and the cost of its installation should be considered together. These costs are comparatively high in British Columbia orchards, with either sprinkler or furrow irrigation.

This is due in part to the high costs of materials and equipment, and in part to such factors as small size of orchard, rough nature of much of the terrain, and sandy nature of much of the soil. These factors vary so widely that costs likewise vary widely. In the following discussion, an average type of 10-20 acre orchard will be used as a basis for cost comparisons.

A number of reasonably accurate records have been obtained on the costs of installing metal and cement fluming in orchards. At present costs for materials and labour, eight-inch metal or cement fluming costs approximately 38¢. per foot installed, and ten-inch 46¢. In addition, there are costs for distribution boxes, screening boxes, etc. Such a system costs at least $70 per acre installed, in the average orchard.

The cost of installing a sprinkler system is usually still higher. In this case, most of the initial cost is for equipment, little of it for labour. An examination of growers' costs reveals costs varying all the way from $40 to $200 per acre. Where the grower has water delivered to his orchard under pressure, the average cost appears to be about $100 per acre. This figure includes the costs of main line pipe and its installation, portable pipe, couplers, sprinklers, screening tank, etc. However, where the grower needs to develop pressure for sprinkling, either with a pump and motor or with a pipe leading to a source of supply of water at a higher elevation, his costs mount. In such cases the average cost appears to be about $130 per acre.

In comparing the costs of installing flume systems and sprinkler systems, it is assumed that one or the other is actually needed. It sometimes happens, however, that a grower who already has a satisfactory fluming system decides that for reasons other than cost he wishes to install a sprinkler system. In such a case the above comparison will not apply.

3. Operating Costs. The chief operating costs are labour, tractor, sundry repairs, and electricity. A large number of records obtained in grower orchards and on the Experimental Station indicate that usually these operating costs are substantially lower with sprinkler irrigation than with furrow irrigation. This is due in large measure to higher labour costs by the furrow method. Each year the grower cultivates, makes new furrows in the spring with tractor and ditcher, connects them to the flumes by hand, and cleans them out in midsummer. The uneven contours encountered in many orchards make it difficult for an irrigator to handle more than 25 or 30 acres working full time during the irrigation season. In comparison with this, a sprinkler operator can usually handle the water with less than half the daily labour costs of those with furrows, and no costs for making or maintaining furrows. On the average, this saving with sprinklers amounts to at least ten labour hours per acre during the season, in addition to tractor hours.

Where the sprinkler system requires the development of pressure with a pump and motor, the costs of electricity are substantial. With the low pressure sprinklers, such as are used in orchards, pumping heads of 50 to 70 feet are usually required. With electricity charged for at the rate of $4.50 per horse power per month, the annual costs for this item usually run about $3.50 to $4.00 per acre for the season. Where the water is pumped from a lake or river, the cost of electricity is often no higher for sprinkler irrigation than for furrow irrigation, because of the need for less water by the former method.

4. Effects on Other Costs. No attempt has been made to assess the effects of sprinkler irrigation on other costs. Growers who have changed to sprinklers claim a reduction in cost of handling the cover crop. They find mowing to be cheaper than cultivating. They also claim that the elimination of furrows reduces slightly the cost of each orchard operation such as spraying, thinning, picking and hauling, and that the over-all reduction for these operations is substantial.

It will be seen from the above discussion that only in certain items of cost has it been possible to compare sprinkler irrigation and furrow irrigation with any degree of accuracy. It is of interest to note how these particular items balance against one another.

The only satisfactory way of making a final cost comparison is on the basis of annual operating costs, including interest and depreciation. It should be sufficient to consider only the estimated *differences* between the two methods. The average difference in cost of equipment and installation is possibly $30 per acre where water is delivered under pressure, and about $60 per acre where a pump and motor are required to develop pressure for sprinkling. If 12½ per cent is allowed annually for depreciation and interest, to cover the additional cost of sprinkler equipment at $30, this would amount to an added $3.75 per acre where water is delivered under pressure, less an estimated saving of $7.50 per acre for labour and tractor power or an apparent net saving of $3.75 per acre. Where a pump is required and the additional investment amounts to $60 per acre, the added overhead would be $7.50 per acre. This would be offset by the annual saving of around $7.50 per acre for labour and tractor. However, there would still be the added cost for electric power to the pump of about $4.00 per acre as compared with furrow irrigation.

It should be clearly understood that the above estimates represent an average for 10- to 20-acre orchards only and that there are wide variations from these figures. As already noted, both costs of irrigation equipment and hours of irrigation labour vary widely from orchard to orchard. Every orchard should, therefore, be considered as an individual problem in so far as the design and cost of the irrigation system are concerned and the probable savings in labour and expense with any particular method of irrigation.

It should be emphasized again that these comparisons of the sprinkler method and the furrow method apply only to those conditions encountered in the orchard districts of the southern interior of British Columbia. They do not necessarily apply to other crops, nor to tree fruits in other areas.

SUMMARY

Sprinkler irrigation of orchards was started in British Columbia about 1930, but did not become popular with growers until portable pipe was placed on sale in 1945. About 30 per cent of the orchards are now irrigated by sprinkling. Low-pressure, undertree rotary sprinklers are used almost entirely.

In comparison with furrow irrigation, the sprinkler method has brought about a marked reduction in soil erosion. It has also induced better growth

of cover crops, made orchard operations easier to perform, provided more satisfactory soil moisture conditions, saved water, saved labour, and reduced difficulties from seepage water.

On the other hand, some slight difficulty has been encountered from increased brown rot of peaches, fire blight of pears, splitting of cherries and apricots. Some growers using sprinklers are over-irrigating, or are not applying the water uniformly enough, or are not screening the water adequately. Some sprinkler systems have been poorly engineered, or contain equipment poor in quality. Irrigation districts have encountered some difficulty in measuring water under pressure.

Cost comparisons of furrow irrigation and sprinkler irrigation indicate that in Okanagan Valley orchards the former is usually cheaper to install and the latter cheaper to operate. When all items of cost are taken into consideration, they appear to average approximately the same by the two methods.

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STUDIES ON THE COMPETITION OF CRESTED WHEATGRASS WITH PERENNIAL NATIVE SPECIES[1]

D. H. Heinrichs[2] and J. L. Bolton[3]

Experimental Station, Swift Current, Sask.

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INTRODUCTION

Crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) has been used extensively during the past fifteen years in the drier parts of Saskatchewan and Alberta for regrassing abandoned farm lands and depleted range pastures. In many sections it is the only grass generally recommended for these purposes. In view of this recognized economic importance of the species, it was decided to obtain more exact information on its reaction to competition from established stands of perennial native species. For this purpose, permanent quadrats were established at Mortlach, Saskatchewan, in 1938 on selected sites. These quadrats were recharted in 1940 and another group initiated at Webb, Saskatchewan, the same year. Unfortunately, reductions of staff and equipment during the war years, and for some time afterwards, prevented further study of the quadrats until 1948. At this time, recharting was undertaken and the results have been summarized for presentation in this paper.

LITERATURE REVIEW

Hubbard (5) reported data extending over a 20-year period from 1928 to 1948. He found that crested wheatgrass controlled annual weeds even when seeded in rows 3 feet apart. However, it did not invade adjacent stands of native sod dominated by blue grama grass (*Bouteloua gracilis* (H.B.K.) Lag.) and common speargrass (*Stipa comata* Trin. and Rupr.). On the other hand, these grasses invaded established stands of crested wheatgrass and the invasion was considerably increased when the area was heavily spring grazed as compared to complete protection from grazing. Crested wheatgrass seeded into sod was not successful unless the native species had been first depleted by drought or cultivation. However, once crested wheatgrass was established in native sod it increased in basal area, although the increase was small unless there was protection from grazing. Allred (1) commented on studies and observations covering the Northern Great Plains. He noted that crested wheatgrass migrates successfully into communities of annual weeds and that minor migrations into open stands of blue grama grass have taken place. He also reported that a thrifty stand of crested wheatgrass had become established in a 25 per cent stand of saltgrass (*Distichlis stricta* (Torr.) Rydb.). However, in regard to climax communities, Allred states: "Although such cases have been reported, I have never seen a situation where crested wheatgrass has migrated into a climax stand of grasses or even produced competitive stands when it has been drilled into them." Blaisdell (2) studied the

[1] Contribution from the Division of Forage Plants, Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Canada.

[2] Agricultural Research Officer, Forage Crops Division, Experimental Station, Swift Current, Saskatchewan.

[3] Agricultural Research Officer, Dominion Forage Crops Laboratory, Saskatoon, Saskatchewan, formerly Agricultural Supervisor, Experimental Station, Swift Current, Saskatchewan.

development of crested wheatgrass and other grasses when they were seeded prior to, concurrently with, and subsequent to sagebush (*Artemisia tridentata* Nutt.) and (*A. tripartita* Rydb.). His results showed that sagebush did not invade an established stand of crested wheatgrass but that when seeded concurrently with crested wheatgrass the sagebush was suppressed at first but later gained a prominent position in the stand. Sagebush stands two years old or older were not greatly affected by crested wheatgrass seeded into them and the older the stands of sagebush the more difficult it was for the crested wheatgrass to become established. The sagebush-grass mixtures, however, gave much higher total yields than sagebush alone. Pavlychenko (7) studied competition between crested wheatgrass and perennial weedy species after the grass had been seeded into well established stands of the weeds. He reported that sow thistle (*Sonchus arvensis* L.) was completely suppressed in three years, Canada thistle (*Circium arvense* (L.) Scop.) in five years, and that quackgrass (*Agropyron repens* L.) was almost gone in four years. Poverty weed (*Iva axillaris* Pursh), leafy spurge (*Euphorbia Esula* L.), field bindweed (*Convolvulus arvensis* L.), and hoary cress (*Cardaria Draba* (L.) Desv.) had not disappeared after four years of competition but only weak plants were left. Hull and Stewart (6) found that crested wheatgrass survived and spread in stands of wheatgrass (*Bromus tectorum* L.). Reitz *et al.* (9) recommended crested wheatgrass for reseeding abandoned farm lands occupied by Russian thistle (*Salsola pestifer* A. Nels.) and tumbling mustard (*Sisymbrium altissimum* L.), but obtained only scattered stands when it was seeded into native sod. They concluded that the native species must be more or less completely subdued before successful stands of crested wheatgrass can become established. Westover and Rogler (11) state that weeds are not likely to cause trouble in closely drilled stands of crested wheatgrass. Peake and Chester (8) and Clarke and Heinrichs (4) found crested wheatgrass the most suitable species for reseeding abandoned farm lands. They also reported that it replaced pasture sage (*Artemisia frigida* Willd.) in three years after seeding.

METHODS OF STUDY

The permanent square meter chart quadrat was used almost exclusively in the studies. The only exception was a permanent belt transect established on the Mortlach area. In all cases the methods of locating and charting the quadrats and transect were similar to those described by Weaver and Clements (10). The basal area of each plant was taken to be the area occupied by its vertical projection at a point about 2 inches above the ground surface. Actual areas were estimated from the charts by the use of transparent squared paper. The quadrats on the Mortlach area were numbered from 1 to 10 and those on the Webb area from 11 to 24.

DESCRIPTION OF STUDY AREAS

Mortlach, Saskatchewan

The Mortlach study area was located on Section 32, Township 17, Range 1, west of the 3rd meridian. The actual field studied had been seeded to Fairway crested wheatgrass in the fall of 1936 at a rate of 10 pounds per acre in rows 6 inches apart. At the time of seeding the field

was abandoned farm-land. The date of last cultivation was unknown but it was apparent that the field had not been cropped for several years. Part of the field was in the annual weed stage but portions of it, particularly around the edges, were dominated by native perennial species. An excellent stand of crested wheatgrass had become established wherever it was seeded among the annual species. Among perennial species the stand was thinner but was considered sufficient to eventually dominate if it was successful in competing with the native species.

At no time during the period of study was the area grazed except during the fall and winter after all vegetation had matured. In occasional years the crop was harvested for hay.

The soil texture of the Mortlach area is a sandy loam and is well drained except for a small dry slough or shallow depression. Quadrat 1 was located in the centre of the slough, quadrat 2 at the edge, and quadrats 3, 4, 5, and 6 about half-way up the slope. The transect extended from high ground down to the edge of the depression. Quadrats 7, 8, 9, and 10 were located on surrounding high ground. Representative samples of soil from the 0-6 inch layer and the 6-12 inch layer were analysed for soluble salt content. The results are presented in Table 1.

The analyses shown in Table 1 are typical of similar locations in Saskatchewan. The soluble salts in depressions leach downwards and a later lateral movement results in their deposition by capillary action near the surface of the slope. Consequently, these slopes tend to be dominated by characteristically saline species such as alkali grass (*Distichlis stricta* (Torr.) Rydb.) and alkali cordgrass (*Spartina gracilis* Trin.).

The nearest detailed climatic records were those of the Moose Jaw Station about 25 miles east of the study area. During the 10-year period 1939-1948, the mean maximum temperature for the months May-October inclusive was 68.1° F. The corresponding mean rainfall was 11.3 inches. Temperature records varied between a low of 65.4° F. in 1945 to a high of 70.5° F. in 1940. Rainfall data ranged from 8.1 inches in 1948 to 18.4 inches in 1942. It is believed that similar general climatic conditions prevailed at Mortlach. The heavy rainfall and low temperatures (mean of 65.8° F.) in 1942 probably caused flooding. The effect of this on the species composition of quadrats 1 and 2 will be discussed later.

TABLE 1.—SOLUBLE SALT CONTENT OF SOIL SAMPLES TAKEN FROM THREE DIFFERENT LOCATIONS AT MORTLACH

Location of sample	Depth of soil	Soluble salt content in per cent					
		$CASO_4$	$MgSO_4$	NA_2SO_4	$NaHCO_3$	NaCl	Total
	(in.)						
Side hill near quadrats 3 and 4	0–6	0.061	0.025	—	0.049	0.020	0.155
	6–12	0.343	0.658	0.694	0.015	0.058	1.768
Highland near quadrat 9	0–6	0.017	0.020	—	0.025	0.010	0.072
	6–12	0.020	0.020	—	0.018	0.010	0.068
Slough near quadrat 1	0–6	0.024	0.010	—	0.010	0.012	0.056
	6–12	0.020	0.015	—	0.013	0.010	0.058

Webb, Saskatchewan

The Webb study area was located on Section 2, Township 15, Range 16, west of the 3rd meridian. The field on which the quadrats were situated was seeded to Fairway crested wheatgrass in April, 1939 and is in a community pasture that was grazed moderately to heavily every year from 1940 to 1948. Drainage is good throughout and the soil texture is a fine sandy loam to sandy loam. Quadrats 11 to 15, inclusive, represented abandoned farm-land and flat topography. The remainder (Numbers 16-24, inclusive) were located on the south and west slopes of a high knoll where the soil had never been broken although at the time of seeding the native species were in a badly depleted condition caused by overgrazing.

As at Mortlach, no detailed climatic data were recorded adjacent to the study area. However, records were available at Swift Current about 20 miles northeast of the project. The mean maximum temperature at Swift Current from May to October, inclusive, for the 8-year period 1941-1948 was 65.9° F. The corresponding mean season rainfall was 11.3 inches. Seasonal temperature means varied from 63.2° F. in 1942 and 1945 to 68.8° F. in 1944. Seasonal rainfall ranged from 8.6 inches in 1948 to 17.9 inches in 1942. There was a remarkably close agreement of temperature and rainfall data from Moose Jaw and Swift Current. This suggests that these two stations, and hence the Mortlach and Webb study areas, have similar climatic conditions.

SUMMARY OF COMPETITION STUDIES

Mortlach Area

Belt Transect.—The belt transect was charted in study competition under varying soil moisture and soil salinity conditions. Each section of the transect was one meter long and three decimeters wide—all 9 sections forming a continuous transect from the dry upland down to the edge of the slough. Sections A, B, and C represent a dry situation at the top of the slope, sections D, E, and F moderately good moisture conditions with relatively high salt content (see Table 1) midway down the slope, and sections G, H, and I favourable moisture levels near the edge of the slough. Since these three general conditions seemed to form natural divisions the data were grouped according to conditions of soil moisture and soil salinity and are so presented in Table 2.

In 1938 the crested wheatgrass plants were small but well established and their increase in basal cover by 1940 and 1948 was due mainly to increase in size of plants rather than to the establishment of new seedlings. As indicated by the data in Table 2, crested wheatgrass dominated all sections of the transect by 1948. This dominance was very largely at the expense of western couchgrass (*Agropyron Smithii* Rydb.). The latter had originally dominated the area but by 1948 it was reduced to a few scattered plants in the moister locations and had disappeared entirely from the drier portions of the site. Wild barley (*Hordeum jubatum* L.), sweet grass (*Hierochloe odorata* (L.) Wahl.), and goldenrod (*Solidago* spp.) were initially present near the edge of the slough but were crowded out by 1948. Smartweed (*Persicaria* sp.) was the principal broad-leaved plant in the moister sections of the transect and appeared to be little affected by competition

TABLE 2.—BASAL COVER IN PER CENT OF ALL SPECIES PRESENT IN THE BELT TRANSECT IN 1938, 1940, AND 1948, AND THE RATIO OF THE BASAL COVER OF CRESTED WHEATGRASS TO ALL OTHER SPECIES AT EACH DATE OF CHARTING

Transect sections	Year	Basal cover in per cent									Ratio crested wheatgrass to all others
		Crested wheatgrass	Western couchgrass	Wild barley	Sweet grass	Beaked sedge	Goldenrod	Smartweed	Yarrow	Total	
A, B, and C	1938	1.67	14.67	—	—	—	—	—	—	16.34	1 : 8.78
	1940	5.07	27.18	—	—	—	—	—	—	32.25	1 : 5.36
	1948	18.19	2.05	—	—	—	0.10	—	0.07	20.41	1 : 0.12
D, E, and F	1938	0.67	13.37	—	—	0.02	—	0.22	—	14.28	1 : 20.31
	1940	4.22	29.11	—	—	—	—	0.60	—	33.93	1 : 7.04
	1948	16.80	0.54	—	—	0.34	1.03	0.30	—	19.01	1 : 0.13
G, H, and I	1938	3.07	1.20	1.00	0.30	—	0.07	1.71	—	7.35	1 : 1.39
	1940	13.73	2.62	0.03	0.78	—	0.09	1.06	—	18.31	1 : 0.33
	1948	24.31	—	—	—	0.30	—	1.29	—	25.90	1 : 0.07

from the crested wheatgrass. It is of interest that beaked sedge (*Carex rostrata* Stokes) was able to invade the lower sections and goldenrod and yarrow (*Achillae lanulosa* Nutt.) the dry upper sections of the transect.

Quadrats 1 and 2.—Quadrat No. 1 was located in the centre of the shallow slough and No. 2 at the edge. Both of these quadrats were dominated by wild barley in 1938. Table 3 records the changes in basal cover as measured from 1938 to 1948, and Figure 1 illustrates the changes that occurred in quadrat 2.

Wild barley is a common species on low-lying soils that often show a high content of soluble salts. Observations indicate that it is resistant to flooding. Bolton and McKenzie (3) have reported that crested wheatgrass is readily killed out by short periods of spring flooding. No accurate records of surface conditions were taken at Mortlach from 1940 to 1948 but flooding likely occurred in the slough—probably in 1942. This would account for the disappearance of crested wheatgrass in quadrat No. 1. However, the reason is not apparent why wild barley did not repossess the quadrat after the crested wheatgrass died out since its method of seed dispersal permits rapid invasion of denuded area. Probably invasion by wild barley did occur and it was followed in the succession by other moisture-loving species, namely, beaked sedge, fowl meadow grass (*Poa pallustris* L.), Baltic rush (*Juncus ater* Rydb.), and smartweed. In any case the data presented in Table 3 show that in the absence of flooding crested wheatgrass eliminated wild barley almost entirely in two years in both quadrats No. 1 and No. 2.

Quadrats 3, 4, 5, and 6.—These quadrats were located on the west-facing slope up from the shallow slough. The soil was high in soluble salts showing 0.155 per cent in the 0-6 inch layer and 1.768 per cent in the 6-12 inch layer (see Table 1). Alkali grass was the dominant species in quadrats 4, 5, and 6 and alkali cordgrass in quadrat 3. Both of these species are regarded as being alkali-tolerant and are indigenous to soils high in soluble salt content. The data recorded in basal cover for the above quadrats are summarized in Table 4.

The relationship between crested wheatgrass and alkali grass as summarized in Table 4 is of particular interest. Alkali grass dominated quadrats 4 and 6 in 1938 but was of relatively minor importance in quadrats 3

TABLE 3.—BASAL COVER IN PER CENT OF ALL SPECIES PRESENT IN QUADRAT NUMBERS 1 AND 2 AND RATIO OF CRESTED WHEATGRASS TO ALL OTHER SPECIES

Quadrat No.	Year	Basal cover in per cent							Ratio crested wheatgrass to all others
		Crested wheat-grass	Wild barley	Beaked sedge	Fowl meadow grass	Baltic rush	Smart-weed	Total	
1	1938	1.67	10.70	0.07	—	—	—	12.44	1 : 6.45
	1940	10.90	1.70	0.03	—	—	—	12.63	1 : 0.16
	1948	0.00	0.00	2.20	4.39	0.76	3.04	10.39	—
2	1938	5.22	8.72	—	—	—	—	13.94	1 : 1.67
	1940	16.56	0.16	—	—	—	—	16.72	1 : 0.01
	1948	29.28	—	—	—	—	—	29.28	—

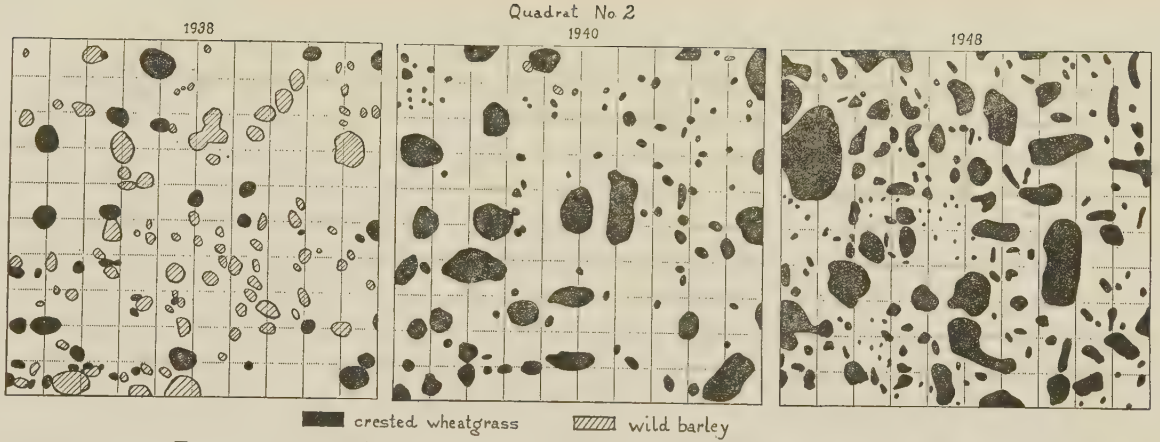

FIGURE 1. Charts of basal cover on quadrat 2 as recorded in 1938, 1940, and 1948.

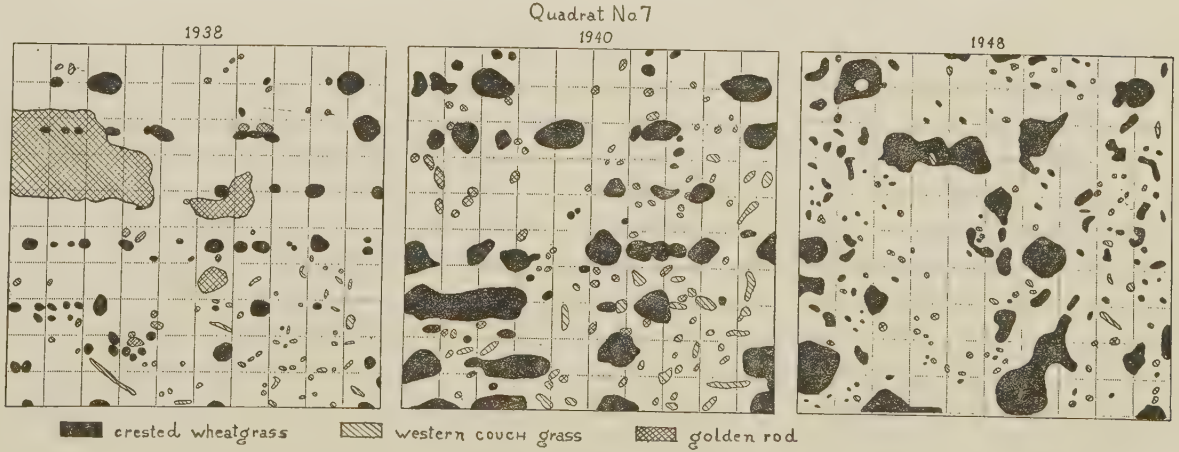

FIGURE 3. Charts of basal cover on quadrat 7 in 1938, 1940, and 1948.

TABLE 4.—BASAL COVER IN PER CENT OF ALL SPECIES PRESENT IN QUADRATS 3, 4, 5, AND 6 AS RECORDED IN 1938, 1940, AND 1948

Quadrat	Year	Basal cover in per cent						Ratio crested wheatgrass to all others
		Crested wheatgrass	Alkali grass	Alkali cordgrass	Wild barley	Pasture sage	Total	
3	1938	2.70	2.87	9.14	—	0.04	14.75	1 : 4.46
	1940	10.85	7.10	7.16	—	0.04	25.15	1 : 1.32
	1948	9.96	15.81	—	—	0.41	26.18	1 : 1.63
4	1938	3.90	24.80	0.44	—	—	29.14	1 : 6.47
	1940	14.22	27.18	—	—	—	41.40	1 : 1.90
	1948	14.83	20.47	—	—	—	35.30	1 : 1.38
5	1938	3.54	1.44	—	1.00	—	5.98	1 : 0.69
	1940	11.60	3.52	—	—	—	15.12	1 : 0.30
	1948	11.08	26.91	—	—	—	37.99	1 : 2.43
6	1938	2.90	14.17	—	0.19	—	17.26	1 : 4.95
	1940	9.47	23.16	—	—	—	32.63	1 : 2.45
	1948	13.23	16.81	—	—	—	30.04	1 : 1.27

and 5. By 1948 it had not only maintained its importance in quadrats 4 and 6 but had become the principal species in 3 and 5. In all cases crested wheatgrass increased rapidly in basal cover from 1938 to 1940 and remained relatively stable from 1940 to 1948. A careful examination of Figure 2 shows that, although certain of the original crested wheatgrass plants had disappeared by 1948, new ones had developed from shattered seed. The general conclusion reached is that crested wheatgrass will not crowd out alkali grass but it can become established and will make satisfactory growth in vigorous stands of alkali grass.

Alkali cordgrass had completely disappeared by 1948, as had also the few original plants of wild barley. These effects may have been caused by increased pressure from either alkali grass or crested wheatgrass. Probably the crested wheatgrass replaced the alkali cordgrass since the latter originally was growing in association with the alkali grass. Adequate check plots containing no crested wheatgrass would have been very useful in this instance. Pasture sage increased in quadrat 3 although it did not invade quadrats 4, 5, or 6.

Quadrats 7, 8, 9, and 10.—These quadrats were located on dry upland soil with a low content of soluble salts (see Table 1). They were charted to study competition between crested wheatgrass and goldenrod on quadrats 7, 8, and 9, and pasture sage on quadrat 10. Both species are common perennial pasture weeds. Unfortunately, quadrat 10 could not be located in 1948 and hence only data for 1938 and 1940 were recorded. Table 5 presents a summary of data on per cent basal cover and Figure 3 illustrates the chart taken from quadrat 7.

As indicated in Table 5, crested wheatgrass increased from 1938 to 1940 and then remained relatively constant in basal cover. Goldenrod decreased in all quadrats during the 10-year period and the decrease was particularly marked in quadrat 7 where the stand of this weed was very

TABLE 5.—BASAL COVER IN PER CENT OF ALL SPECIES PRESENT IN QUADRATS 7, 8, 9, AND 10 IN THE YEARS 1938, 1940, AND 1948

Quadrat No.	Year	Basal cover in per cent							Ratio crested wheatgrass to all others
		Crested wheat-grass	Western couch-grass	Sweet grass	Wild barley	Golden-rod	Pasture sage	Total	
7	1938	5.18	1.30	—	0.08	9.32	—	15.88	1 : 2.07
	1940	16.34	2.10	—	—	1.50	—	19.94	1 : 0.22
	1948	16.22	0.74	—	—	0.50	—	17.46	1 : 0.08
8	1938	3.76	—	1.86	0.04	1.04	—	6.70	1 : 0.78
	1940	13.08	—	—	—	1.54	—	14.66	1 : 0.12
	1948	16.22	—	—	—	0.49	—	17.12	1 : 0.06
9	1938	5.99	—	—	—	1.10	0.08	7.17	1 : 0.20
	1940	18.98	—	—	—	0.10	0.15	19.23	1 : 0.01
	1948	18.99	—	—	—	0.04	0.92	19.95	1 : 0.05
10	1938	3.76	0.08	—	—	—	8.48	12.32	1 : 2.28
	1940	14.90	0.04	—	—	—	0.48	15.42	1 : 0.03

heavy in 1938. In no case, however, was goldenrod completely eliminated. The two species of goldenrod present (*Solidago dumetorum* Lunell) and (*S. Lunellii* Rydb.) are vigorous, rather tall-growing species characteristic of abandoned farm-lands and favoured locations in native sod. Invasion by goldenrod was noted previously in the discussion of the transect (see Table 2). Unfortunately, the species was not determined in that case. It is possible that it was *S. missouriensis* Nutt. which is a common species on dry upland soils and may have better competitive qualities in relation to crested wheatgrass than the species found in quadrats 7, 8, and 9.

Traces of wild barley in quadrats 7 and 8 were quickly replaced. Sweet grass, as found in quadrat 8, also had disappeared by 1940. The situation with regard to pasture sage is not clear. In quadrat 3 (see Table 4) and in quadrat 9 it increased in basal cover. However, in these cases the increase was due to increase in size of small plants established previous to the first charting in 1938. On the other hand, in quadrat 10, there was a marked reduction in the basal cover of pasture sage from 1938 to 1940 and this agrees with general observations from field seedings as described in the review of literature. It is regrettable that it was not possible to re-locate quadrat 10 in 1948 and that additional quadrats containing pasture sage were not established in 1938.

Webb Area

The quadrats at Webb have been separated into two groups for the purposes of discussion and presentation of data. Quadrats 11 to 15, inclusive, were located and charted to study the effect of crested wheatgrass on established stands of hoary sagebush (*Artemisia cana* Pursh). The second group, quadrats 16 to 24, inclusive, were intended to supplement the Mortlach data by including additional common native species and duplicating others.

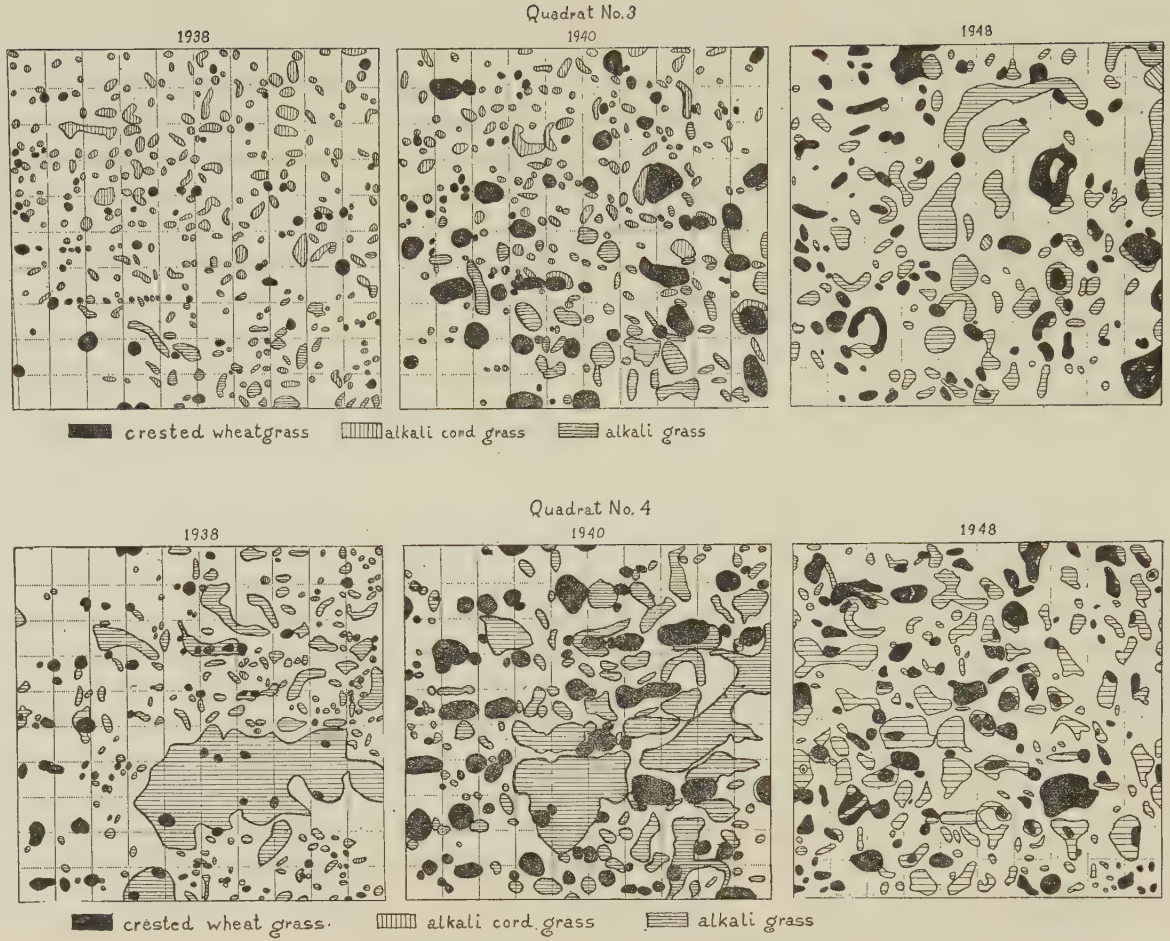

FIGURE 2. Charts of basal cover on quadrats 3 and 4 as recorded in 1938, 1940, and 1948.

Quadrats 11 to 15, inclusive.—Basal area data are presented in Table 6, and Figure 4 represents chartings made on quadrat 14 which is fairly typical of the group.

The data presented in Table 6 show that crested wheatgrass can become established in a stand of hoary sagebush plants and that it will attain a normal stand in 8 years or less. Competition between the two species does not appear to be severe, possibly because of different root systems. However, any competitive advantage apparently is in favour of crested wheatgrass. Very few new plants of hoary sagebush became established and in quadrats where the number of sagebush plants was high in 1940 there had been a considerable decrease by 1948 (see Figure 4). On the other hand, many new seedlings of crested wheatgrass invaded the quadrats especially where the original number was very low.

TABLE 6.—BASAL COVER IN PER CENT OF ALL SPECIES PRESENT IN QUADRATS 11, 12, 13, 14, AND 15 IN THE YEARS 1940 AND 1948

Quadrat	Year	Basal cover in per cent					Ratio crested wheatgrass to all others
		Crested wheatgrass	Hoary sagebush	Pasture sage	Broomweed	Total	
11	1940	1.12	0.64	—	—	1.76	1 : 0.57
	1948	14.16	3.56	0.08	—	17.80	1 : 0.26
12	1940	0.41	1.22	0.02	—	1.65	1 : 3.31
	1948	16.76	3.60	0.40	—	20.76	1 : 0.24
13	1940	0.14	1.84	0.23	—	2.21	1 : 14.79
	1948	12.84	2.72	0.52	1.60	17.68	1 : 0.38
14	1940	0.09	1.70	—	—	1.79	1 : 18.89
	1948	11.64	4.16	—	0.52	16.32	1 : 0.40
15	1940	2.10	0.39	—	—	2.49	1 : 0.19
	1948	14.72	3.44	—	—	18.16	1 : 0.23

There was some indication that pasture sage could invade the quadrats and also improve its position when originally present. However, it did not become an important constituent in any case. Broomweed (*Gutierrezia diversifolia* Greene) invaded both quadrats 13 and 14 and it is possible that this species may have a competitive advantage over crested wheatgrass.

Quadrats 16 to 24, inclusive.—Quadrats 16 to 24, inclusive were located on an extremely dry knoll which had never been cultivated. Table 7 presents data on basal cover and Figure 5 represents the chartings made on quadrat 16.

The data in Table 7 indicate two very strong competitors in relation to crested wheatgrass. Both blue grama grass and involute sedge (*Carex Eleocharis* Bailey) maintained or increased their basal cover from 1940 to 1948 in practically all quadrats where they occurred. Involute sedge in particular gained considerably. The above gains, however, were not made at the expense of crested wheatgrass. The latter increased very markedly in all quadrats except No. 19 where few seedlings of this species occurred

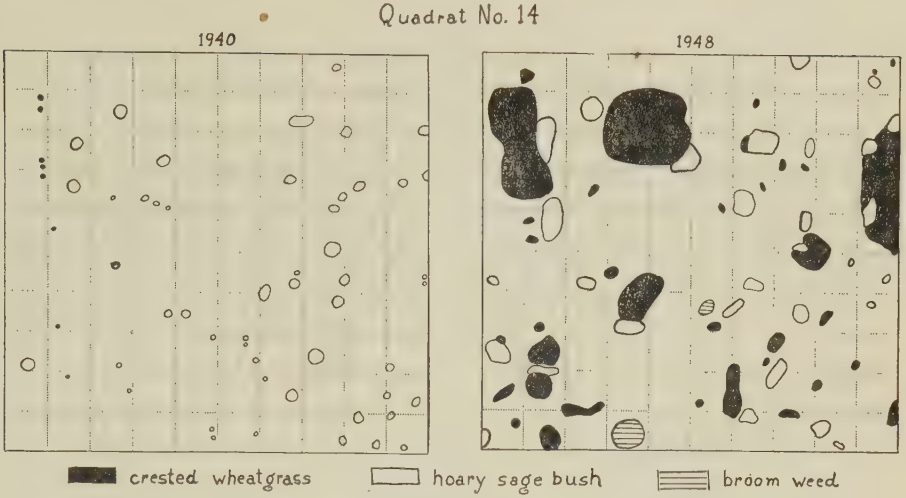

FIGURE 4. Charts of basal cover data on quadrat 14 in 1940 and 1948.

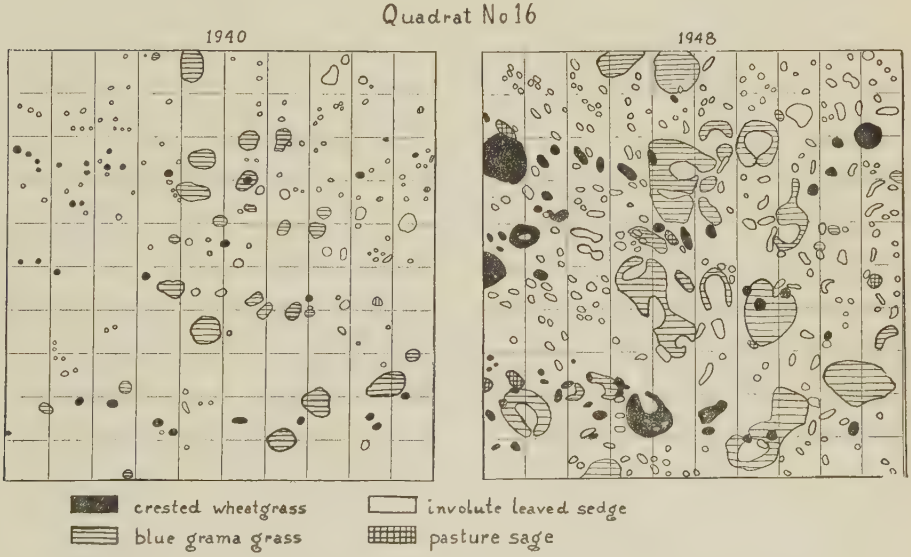

FIGURE 5. Charts of basal cover data on quadrat 16 in 1940 and 1948.

and a very thick stand of blue grama grass was present in 1940. As stated previously, this group of quadrats was in a very dry location, the basal cover in 1940 being very low and in a badly depleted condition. Hence, it is likely that much of the recorded increase was due to the occupation of bare ground and that little competition actually took place. If so, then it is probable that the cover attained by 1948 is about the maximum possible. A further charting at a later date should indicate whether crested wheatgrass will give way to blue grama grass and involute sedge, or *vice versa*, or whether all three species will retain their relative positions as of 1948. Common speargrass generally maintained its position in the quadrats but in no case was it abundant enough to be very important. Western couch-

TABLE 7.—BASAL COVER IN PER CENT FOR SPECIES PRESENT IN QUADRATS 16 TO 24, INCLUSIVE, IN THE YEARS 1940 AND 1948

Quadrat No.	Year	Basal cover in per cent										Ratio crested wheatgrass to all others
		Crested wheatgrass	Blue grama grass	Western couchgrass	Common speargrass	Involute-leaved sedge	Thread-leaved sedge	Pasture sage	Nuttall's atriplex	Prairie sage	Total	
16	1940	0.56	2.35	0.07	—	1.54	—	—	—	—	4.52	1 : 7.07
	1948	4.08	11.11	—	—	5.28	—	0.64	—	—	21.11	1 : 4.17
17	1940	1.33	13.11	—	0.12	0.74	—	—	—	—	15.30	1 : 10.50
	1948	7.08	26.64	—	0.32	1.04	—	0.36	—	—	35.44	1 : 4.01
18	1940	1.51	18.61	0.02	—	0.17	—	—	—	—	20.31	1 : 12.45
	1948	6.94	19.64	—	—	0.76	—	—	—	—	27.34	1 : 2.94
19	1940	0.20	31.61	0.68	—	3.27	—	—	—	0.38	36.14	1 : 179.70
	1948	0.08	26.84	—	0.52	8.44	—	0.48	—	1.08	37.44	1 : 467.00
20	1940	1.20	—	0.23	1.12	—	—	—	—	—	2.55	1 : 1.12
	1948	5.68	—	1.64	0.80	—	—	3.60	—	—	11.72	1 : 1.06
21	1940	1.29	—	0.31	1.73	0.08	—	—	—	—	3.41	1 : 1.64
	1948	14.84	—	—	1.92	0.16	—	—	—	—	16.92	1 : 0.14
22	1940	0.68	—	3.72	0.06	0.17	—	—	—	0.27	4.90	1 : 6.21
	1948	8.36	—	0.16	0.48	2.56	0.32	3.20	—	2.08	17.16	1 : 1.05
23	1940	0.73	—	5.35	—	0.04	—	—	—	—	6.12	1 : 7.38
	1948	9.12	0.04	—	—	2.76	—	1.40	—	—	13.32	1 : 0.46
24	1940	1.18	—	0.03	0.12	0.09	—	—	4.81	—	6.23	1 : 4.28
	1948	12.16	—	—	—	0.76	—	0.52	2.56	—	16.00	1 : 0.32

grass reacted much the same as in the Mortlach area and practically disappeared by 1948, except on No. 20 where very few other native species were present. The one plant of Nuttall's atriplex (*Atriplex Nuttallii* S. Wats.) decreased in size to about one-half and no new plants became established. The increase of prairie sage (*Artemisia gnaphalodes* Nutt.) on quadrats 19 and 22 is of interest, as is the invasion of pasture sage in seven of the nine quadrats. This reaction may be associated with the same reasons suggested for the increase or maintenance of stands of blue grama grass and involute sedge. That is, that the maximum cover for the area has been attained only recently and hence that competition between species was not severe during the period studied.

DISCUSSION

In a general analysis of the results presented so far a summary of basal cover in per cent is helpful. The first and final chartings only have been considered in Table 8 and quadrats 1 and 10 have been omitted since the former undoubtedly was affected severely by flooding and no 1948 data were available for the latter.

An appraisal of the data presented in Table 8 shows that there was a large increase in the basal area occupied by crested wheatgrass from the beginning to the end of the period studied. This applies at both Mortlach and Webb, although the increase was much greater at Webb. Such an increase is to be expected only from a strong competitor. The crested wheatgrass plants were very small and relatively undeveloped when first charted and would have been eliminated or at least subdued if the native species had been more aggressive. Most of the increase was due to the growth of established plants but in some cases a significant increase from the growth of new seedlings was noted. In regard to native species, there was an average decrease of 19 per cent in basal cover at Mortlach and an average increase of 54 per cent at Webb. This is evidence, as suggested previously, that the Webb area was in a more depleted condition in 1940 than the Mortlach area was in 1938. The general effect on the average total basal cover was almost to double it at Mortlach and nearly triple it at Webb. This over-all increase in basal cover was entirely due to crested wheatgrass at Mortlach since there was an actual decrease of other species. At Webb crested wheatgrass also contributed largely to the general increase

TABLE 8.—AVERAGE BASAL COVER IN PER CENT AND PER CENT INCREASE IN BASAL COVER FOR 11 QUADRATS[1] AT MORTLACH AND 14 QUADRATS AT WEBB

Constituents of basal cover	Mortlach area			Webb area		
	1938	1948	Per cent increase	1940	1948	Per cent increase
Crested wheatgrass	3.51	17.19	390	0.90	9.89	1000
All other species	10.02	8.13	— 19	6.91	10.62	54
Total basal cover	13.53	25.32	87	7.81	20.51	163

[1] The 3 divisions of the transect as shown in Table 3 were considered 3 quadrats in calculating the data for this table.

since other species increased only 54 per cent while the total increase was 163 per cent. Apparently crested wheatgrass is a strong competitor that can at least maintain its position as compared to certain species and increase greatly at the expense of others.

SUMMARY

1. Crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) of the Fairway variety was seeded into established stands of native perennial species at two locations in Southern Saskatchewan. Changes in basal cover were determined at the end of two years and ten years at one location and at the end of eight years at the other.

2. Crested wheatgrass made very large gains in basal cover at both locations. These gains were greatest, relative to the native species, where the original cover was the lowest.

3. Wild barley (*Hordeum jubatum* L.) and sweet grass (*Hierochloe odorata* (L.) Wahl.) were eliminated within two years. Alkali cordgrass (*Spartina gracilis* Trin.), western couchgrass (*Agropyron Smithii* Rydb.), and goldenrod (*Solidago* sp.) disappeared or were greatly reduced but over a longer period. Alkali grass (*Distichlis stricta* (Torr.) Rydb.), blue grama grass (*Bouteloua gracilis* (H.B.K.) Lag.), involute sedge (*Carex Eleocharis* Bailey), common speargrass (*Stipa comata* (Trin.) Rupr.), hoary sagebush (*Artemisia cana* Pursh), and smartweed (*Persicaria* sp.) were controlled in that they did not prevent crested wheatgrass from taking an important and sometimes dominant place in the habitat. Mature plants of pasture sage (*Artemisia frigida* Willd.) were greatly reduced in basal cover but there were minor invasions by seedlings of this species.

4. It was concluded that crested wheatgrass is a strong competitor with perennial native species under the conditions studied.

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APPENDIX

Common and scientific names of species occurring in the transect and quadrats of the study areas:

Alkali cordgrass	*Spartina gracilis* Trin.
Alkali grass (Saltgrass)	*Distichlis stricta* (Torr.) Rydb.
Baltic rush	*Juncus ater* Rydb.
Beaked sedge (Retrorse sedge)	*Carex rostrata* Stokes
Blue grama grass	*Bouteloua gracilis* (H.B.K.) Lag.
Broomweed	*Gutierrezia diversifolia* Greene
Common speargrass	*Stipa comata* Trin. and Rupr.
Crested wheatgrass	*Agropyron cristatum* (L.) Gaertn.
Fowl meadow grass	*Poa palustris* L.
Goldenrod, low	*Solidago missouriensis* Nutt.
Goldenrod, Lunell's	*Solidago Lunellii* Rydb.
Goldenrod, prairie	*Solidago dumetorum* Lunell
Hoary sagebush	*Artemisia cana* Pursh
Involute-leaved sedge	*Carex Eleocharis* Bailey
Nuttall's atriplex	*Atriplex Nuttallii* S. Wats.
Pasture sage	*Artemisia frigida* Willd.
Prairie sage	*Artemisia gnaphalodes* Nutt.
Smartweed	*Persicaria* sp.
Sweet grass	*Hierochloe odorata* (L.) Wahl.
Thread-leaved sedge (Niggerwool)	*Carex filifolia* Nutt.
Western couchgrass (Western wheatgrass)	*Agropyron Smithii* Rydb.
Wild barley	*Hordeum jubatum* L.
White sage	*Eurotia lanata* (Pursh) Moq.
Yarrow	*Achillea lanulosa* Nutt.

SOME FURTHER OBSERVATIONS ON SMALL BITTER CHERRY[1]

T. B. Lott[2]

Dominion Laboratory of Plant Pathology, Summerland, B.C.

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Further information obtained on small bitter cherry indicates that this disease is becoming increasingly important in the Okanagan Valley of British Columbia. Transmission has now been obtained. The disease has been found in the Lambert variety of sweet cherry in addition to the Bing variety in which it was previously reported (1). The number of natural infections has increased slowly but steadily.

TRANSMISSION

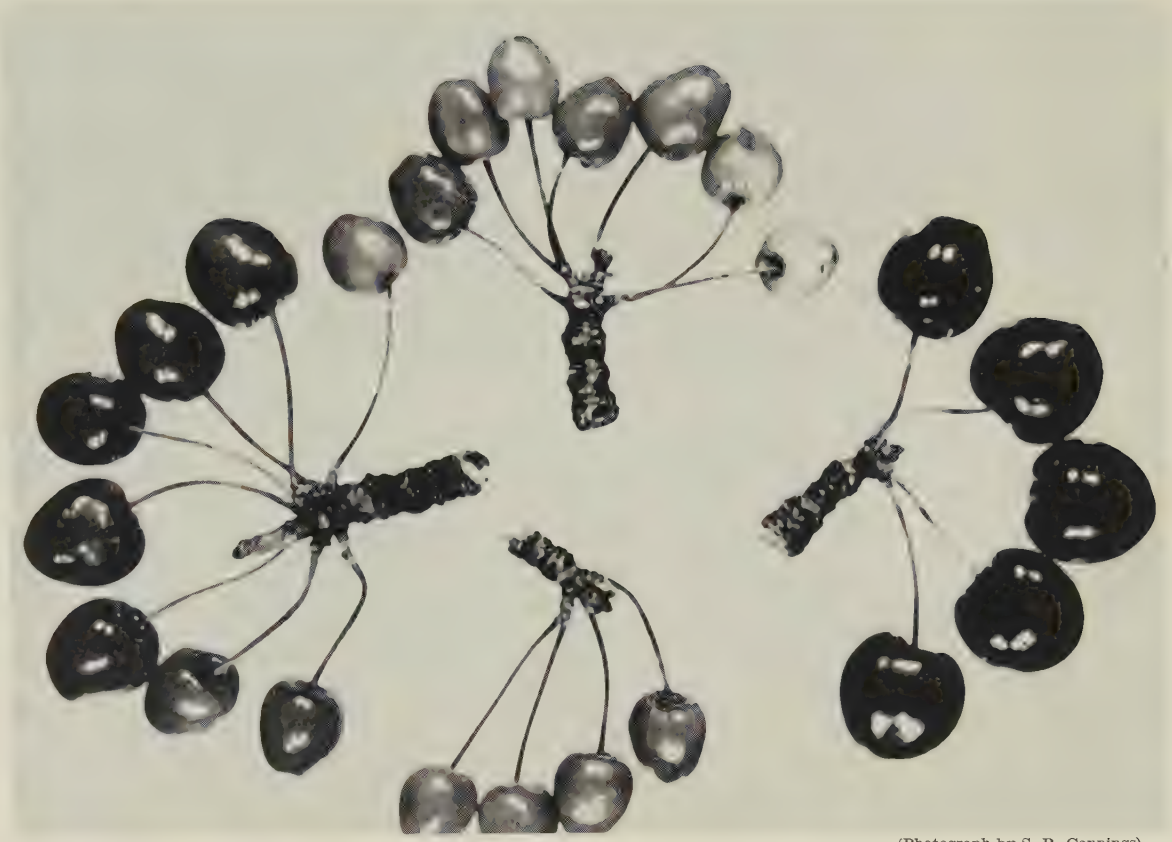
Transmission was obtained for the first time in a single tree in 1949, as a result of inoculation made in 1941. As previously reported eight trees were inoculated by grafting or budding with diseased material in 1941 and 1942, and two trees were inoculated by budding in 1944. The tree in which transmission was obtained in 1949 was one of those inoculated in 1941. Scions from a diseased Bing tree were successfully grafted on to two branches of a young Bing tree, the remainder of which was allowed to grow. One inserted scion grew into a small branch which has consistently produced only normal cherries. The other inserted scion grew into a branch which is now twenty feet high with strong lateral branches, and which was definitely affected with small bitter cherry in 1947, 1948, and 1949. In all three years this branch carried a good crop and the majority of the cherries were normal. In 1947, small bitter cherry was evident in only a few fruits on the lower part of this branch. In 1948 and 1949, the disease could be observed in a small number of cherries scattered through the branch. Transmission first became evident in 1949 when small bitter cherry was observed on the fruits on small branches growing below the points of inoculation. No signs of transmission were observed at this time on the remainder of the inoculated tree which produced a good crop of normal cherries. The other inoculated trees, some of which are still on hand, have shown no signs of transmission.

SYMPTOMS IN THE LAMBERT VARIETY

The symptoms of small bitter cherry in the Lambert variety (Figure 1) are essentially the same as the symptoms in the Bing variety which were described previously. Only three affected Lambert trees have been observed. Two of these were new infections in 1949 while the other has been infected for several years. In these trees some of the cherries were apparently entirely normal and even in the tree that has been infected for several years some branches produced only normal cherries. In some branches small and apparently normal cherries occurred together. In some smaller branches all of the fruits were abnormal. At normal picking time most of the small cherries were bright red like immature cherries,

[1] Contribution No. 1040 from Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

[2] Agricultural Research Officer, Dominion Laboratory of Plant Pathology, Summerland, B.C.



(Photograph by S. R. Cannings)

FIGURE 1. Small bitter cherry in the Lambert variety. All cherries from the same tree.

while a few were light pink and much under-developed. The small cherries were oval in side view, and rounded, not triangular, when viewed from the distal end. In taste the first impression was bitterness, soon superseded by a positively objectionable flavour. Most of the small cherries had the gloss of normal ones. It is particularly noteworthy that the Lambert tree that has been diseased for years produced many cherries that appeared entirely normal. No experimental work has been done on these Lambert trees but the symptoms in Lambert and in Bing are so similar that it appears almost certain that the same disease is involved in both varieties.

SPREAD WITHIN THE INDIVIDUAL TREE

The manner in which small bitter cherry spreads in or through individual trees is of both diagnostic and economic importance. The rate of spread within the individual tree has differed widely in different trees and sometimes in different years in a single tree. Observations made in four successive years have shown that the disease may remain in a naturally infected tree with negligible spread for as much as three years. On the other hand, very extensive spread was recorded one year in a tree in which negligible spread had been recorded the preceding year.

GENERAL

The number of new natural infections and their locations are cause for concern if not alarm. Up to 1946, eight infected trees had been observed in five orchards. By 1949, twenty-two infected trees had been recorded in fourteen orchards. These infections were scattered through the Oliver and Osoyoos districts in the southern part of the Okanagan Valley. No infections have been found farther north.

Small bitter cherry in sweet cherry may be caused by the same virus that causes Western X in peach, but the available information does not warrant any definite statement of relationship. Small bitter cherry has been found only in the part of the Okanagan Valley where Western X is fairly common in peach. Limited experimental work has not demonstrated any relationship. The exact relationship between small bitter cherry and other diseases producing abnormal fruits in sweet cherry is not yet known.

SUMMARY

1. Small bitter cherry is becoming increasingly important in the Okanagan Valley of British Columbia.

2. Transmission has been obtained. Transmission became evident eight years after inoculation, indicating an unusually long incubation period.

3. The disease has been found in the Lambert variety in addition to the Bing variety in which it was previously reported.

4. The symptoms in the Lambert variety are essentially the same as those in the Bing variety.

5. The rate of spread of the disease in the individual tree has differed widely in different trees and sometimes in different years in a single tree.

6. The number of naturally-occurring infections is increasing steadily.

7. Small bitter cherry has only been found where Western X is fairly common in peach but limited experimental work has not demonstrated any relationship.

8. The relationship between small bitter cherry and other diseases causing abnormal fruits in sweet cherry is not yet known.

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